AFRL-IF-RS-TR-2000-16
Final Technical Report
March 2000

AIRFIELD GROUND SAFETY

ORINCON Corporation

Jon Petrescu

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REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	MARCH 2000	Final Oct 97 - Nov 99

4. TITLE AND SUBTITLE AIRFIELD GROUND SAFETY	5. FUNDING NUMBERS C - F30602-97-C-0353 PE - 63160D PR - 4748 TA - 00 WU - 01
6. AUTHOR(S) Jon Petrescu	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) ORINCON Corporation 9363 Towne Centre Drive San Diego CA 92121	8. PERFORMING ORGANIZATION REPORT NUMBER 98-4311-U-0300
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory/IFEA 32 Brooks Road Rome NY 13441-4414	10. SPONSORING/MONITORING AGENCY REPORT NUMBER AFRL-IF-RS-TR-2000-16

11. SUPPLEMENTARY NOTES
Air Force Research Laboratory Project Engineer: Richard Gassner/IFEA/(315) 330-3574

12a. DISTRIBUTION AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.	

13. ABSTRACT *(Maximum 200 words)*

This document is the final report for the Airfield Ground Safety (AGS) program under Air Force Research Laboratory-Rome contract number F30602-97-C-0353. The system developed under AGS, called the Ground Safety Tracking and Reporting System, uses multisensor data fusion from in-pavement inductive loop sensors to address a critical problem affecting out nation's airports: runway incursions. GSTARS is an effective, low-cost solution that provides aircraft and ground vehicle detection, classification (including aircraft type), and origin/destination tracking in all weather and visibility conditions. The system is currently installed at MacDill Air Force Base and provides increased situation awareness and tracking of ground traffic to air traffic controllers in the Tower, and to base Operations and Base Command. GSTARS is based on inductive loop technology coupled with advanced signal processing and predictive networking techniques that provide airport surface traffic surveillance.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Airfield Safety, Classification and Tracking System, Loop Sensor Technology, Data Fusion	56
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

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EXECUTIVE SUMMARY

The number of runway incursions in this country has increased 75 percent from 1993 to 1998, with 325 cases reported in 1998. The number of actual incursions is likely much greater. The most common causes of incursions are failing to hold short of the active runway, turning onto the wrong taxiway, or inadvertently crossing a runway without clearance. Low-visibility conditions and poor situational awareness also contribute to incursions. Several tragic accidents have occurred as a result of aircraft collisions, including one in the Canary Islands in 1977 that killed 583 people, one in Madrid that killed 100 people in 1983, and other accidents in Minneapolis-St. Paul, MN; Detroit, MI; Atlanta, GA; Los Angeles, CA; St. Louis, MO; and Quincy, IL. The need has never been greater to reduce this dangerous and potentially disastrous trend.

The Ground Safety Tracking and Reporting System (GSTARS) was developed under the AGS program to address the growing concerns of airport ground safety and to reduce to potential for runway and taxiway incursions. GSTARS provides increased situational awareness and tracking of ground traffic to air traffic controllers and alerts them to potential runway or taxiway incursions. The system is based on inductive loop technology coupled with advanced signal processing and predictive networking techniques that provide airport surface traffic surveillance. GSTARS operational features include the following:

- Aircraft and ground vehicle detection
- Classification (including aircraft and ground vehicle type)
- Origin/destination tracking
- Visual and audio incursion safety alerts
- Record of ground vehicle movement
- Prediction of runway occupancy of arriving aircraft with an integrated approach radar

As the aircraft passes over the loop sensors, an electronic detector, the IVS-2000, senses the movement of the passing aircraft or ground vehicle, classifies it on the basis of its "electronic signature," processes its speed and location, and transmits the information to the host computer. The host computer processes the data fusion data and provides the information to the Control Tower Display that shows the aircraft location and provides visual and audio alerts to possible incursions or collisions so that the controller can quickly notify the involved vehicles to take evasive action.

In addition to GSTARS, inductive loop technologies may also be integrated into other products or specific airport applications such as ramp movement management systems, "blind spot" taxiway locations, airfield lighting systems, etc.

The FAA is evaluating alternative noncooperative (no aircraft equipage) surface sensor technology for application in an airport environment. The particular and most promising surface sensor being addressed here is the inductive loop. Inductive loops represent a mature technology that has seen wide use in highway/traffic applications for almost 30 years. Neural network technology represents a fairly new technology that has demonstrated good results in certain applications such as pattern recognition and classification. A combination of a system of distributed inductive loops and signal processing using neural network techniques offers the potential for a low-cost surface sensor that could be used to improve surface safety, particularly at lower level airports not presently equipped with an ASDE system.

Working with the FAA, ORINCON developed a prototype demonstration loop-based system using neural network technology at Long Beach Airport (LGB) in California, which is acting as the host test site. LGB handles mostly general aviation flights along with a small level of scheduled air carrier flights. The FAA calls this demonstration system Loop Technology (LOT). GSTARS is the same as LOT, with improvements in power and communications, but without the approach radar interface. LOT is in direct support of the FAA's runway incursion initiatives, which seek to develop near-, mid-, and far-term technologies to apply to the runway incursion problem and aid the controller in improving situational awareness. LGB has been experiencing incursions, but it is probably the type of airport where it is not economically productive to install an ASDE-3.

Operational Concept

The operational concept of LOT is to provide some level of a lower cost automated surface sensor at lower level airports where incursions tend to be more numerous in their occurrence. Most of the automation efforts to date have rightly concentrated on the surface safety and incursion problems at higher level airports where traffic is more dense and complex. The ASDE-3 has been designed to accommodate that level of airport. Something is needed to address airports where ASDE-type equipment will not be installed or the monitoring requirement is too localized to warrant an ASDE-type system. The system employed should offer more flexibility in application (limited application versus full airport), be scalable, and allow for incremental implementation to reduce or manage the cost.

Air traffic controllers can use GSTARS to aid in minimizing the risk of incursion incidents. GSTARS will provide for runway safety zone violation, standard route conformance monitoring, blind spot monitoring, and an operational display of arrival and surface traffic. The system will

be used by local and ground controllers to augment visual observations of aircraft and vehicle movement, and may be used by the controllers under the following conditions:

1. Visibility is less than the most distant point in the active movement area where loops are installed.
2. Traffic is operating in blind spots with respect to the tower.
3. The system is used to verify the position of aircraft or vehicles at specific update points.
4. In the controller's judgment, the system's use will assist in the performance of his/her duties at any time.
5. There are system-generated aural and visual indications of a violation of a runway threshold or an unsafe condition on the runway.
6. There are system-generated aural and visual indications of nonconformance with standard taxi route operation. The GSTARS-derived position and identification information will be used to assist the controllers with the following activities:
7. Formulating clearances and control instructions to aircraft on the movement area.
8. Determining when the runway is clear of aircraft and vehicles prior to a landing or departure.
9. Positioning aircraft and vehicles.
10. Determining the exact location of aircraft, or the relationship to other aircraft on the movement area.
11. Monitoring compliance with control instructions.
12. Confirming pilot-reported positions.
13. Providing directional taxi information (excluding heading) on pilot request.
14. Identifying the type of aircraft to assist in maintaining proper departure separation standards.
15. Determining when an aircraft has lifted off or touched down.

Technical Concept

The GSTARS system uses commercial off-the-shelf (COTS) inductive loop technology and a computer workstation to provide surface surveillance and surface traffic safety processing for aircraft and ground vehicles operating on runways and taxiways where inductive loops are installed. The GSTARS system consists of the following major elements:

1. **Surveillance Subsystem.** The surveillance subsystem forms the heart of a loop-based surveillance system. It consists of the sensor (loop wire), detection component, and tracking component. This subsystem provides track reports to the safety subsystem for display and processing by the safety logic. Inductive loops provide the sensing element for the Loop Detection Component (LDC). The inductive loops consist of three turns of stranded wire that is embedded in the runway or taxiway surface. Inductive loops can be located over the whole runway/taxiway surface or in strategic locations (i.e., troublesome intersections).

2. **Loop Detection Component.** Each inductive loop has an associated LDC. The LDC is located within the controller cabinet, which is usually within 500 to 1,000 feet of the loop itself. Each loop is connected to the LDC via a lead-in cable. In the MacDill AFB installation, each controller cabinet houses up to four LDCs. The LDC provides for the following functions:

   - Detection of aircraft and ground vehicles.
   - Class and speed estimation of aircraft and ground vehicle signatures and single-loop velocity estimates.

3. **Tracking Component (TC).** The TC is a computer workstation that performs loop-to-loop correlation and tracking function position, velocity, and heading based upon kinematics. It also performs data handoff between arrival surveillance data and the loop data from the airport surface.

4. **Safety Subsystem.** The safety subsystem provides for processing of track reports from the surveillance subsystem by the safety logic for detection of runway occupancy and runway safety zone violation.

5. **Controller Display.** The display provides the controller with a situational display of traffic movement in the inductive loop coverage area(s). Aural and visual indications are provided in the event that there is a violation detected by the safety logic (i.e., violation of runway safety zone, entry into blind spot area, etc.).

The System User Manual developed during the AGS program is included as Appendix A.

1.0 AIRFIELD GROUND SAFETY INITIATIVE

1.1 Introduction

The number of runway incursions in this country has increased 75 percent from 1993 to 1998, with 325 cases reported in 1998. The number of actual incursions is likely much greater. The most common causes of incursions are failing to hold short of the active runway, turning onto the wrong taxiway, or inadvertently crossing a runway without clearance. Low-visibility conditions and poor situational awareness also contribute to incursions. Several tragic accidents have occurred as a result of aircraft collisions, including one in the Canary Islands in 1977 that killed 583 people, one in Madrid that killed 100 people in 1983, and other accidents in Minneapolis-St. Paul, MN; Detroit, MI; Atlanta, GA; Los Angeles, CA; St. Louis, MO; and Quincy, IL. The need has never been greater to reduce this dangerous and potentially disastrous trend.

The Air Force has initiated the Airfield Ground Safety (AGS) program to address this problem. One of the emerging technologies to address this problem is based on multisensor data fusion from in-pavement inductive loop sensors and is called the Ground Safety Tracking and Reporting System (GSTARS). This system is an effective, low-cost solution that provides aircraft and ground vehicle detection, classification (including aircraft type), and origin/destination tracking in all weather and visibility conditions. Figure 1 provides a diagram of the GSTARS system installed at MacDill Airfield and its major components. GSTARS provides increased situational awareness and tracking of ground traffic to air traffic controllers in the Tower, and to Base Operations and Base Command at MacDill Airfield. This system alerts users to potential runway or taxiway incursions. The GSTARS system is based in inductive loop technology coupled with advanced signal processing and predictive networking techniques that provide airport surface traffic surveillance.

As an aircraft passes over the loop sensors, an electronic detector, the IVS-2000, senses the change in inductance of the passing aircraft or ground vehicle, classifies it based on its "electronic signature," processes its speed and location, and transmits the information to the host computer. The host computer processes the data and provides the information to the Control Tower display, Base Operations, and Base Command that shows the aircraft/vehicle location and provides visual and audio alerts to possible incursions or collisions.

The GSTARS system provides multisensor data fusion and the tracking system correlates and fuses information across multiple loop sensors to track and classify multiple ground-based aircraft and ground vehicle traffic. The fusion system utilizes a second-order linear Kalman filter to perform kinematic association and state estimation, and a Bayesian Pearl tree to perform classification association and target recognition. A dynamic fused picture of all ground-based

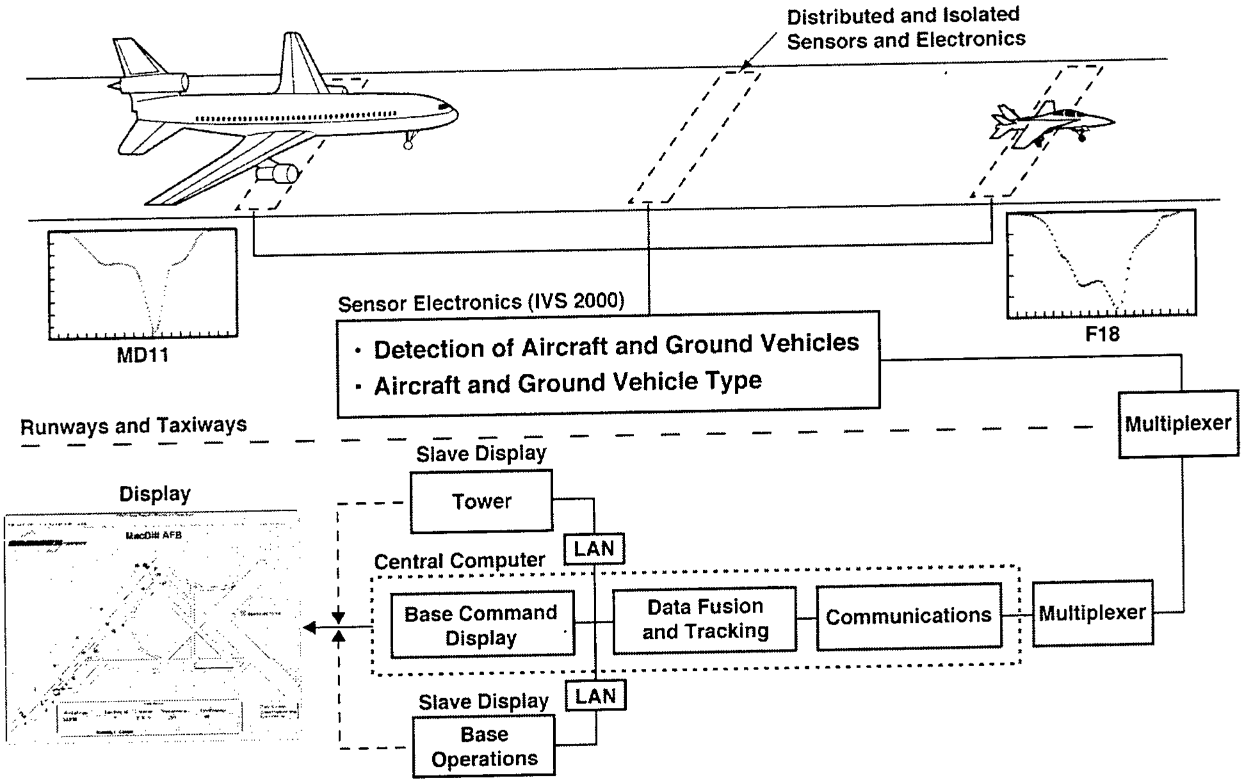

Figure 1. Diagram of GSTARS System

airfield traffic is generated and maintained using the detection and classification capability of the multiple loop sensors.

The five major functions of the multisensor data fusion are the Loop Interface, Track Association, Track Update and Initialization, Track Prediction, and Display Interface. The Loop Interface function receives the loop detection inputs consisting of detection time, loop location, optional speed measurement, and classification. The Track Association function evaluates each new loop detection for association with existing tracks. The Track Update and Initialization function performs the kinematic and classification state update (or initialization). The Track Prediction function extrapolates the position of each track on the display to ensure a smooth motion between loops. If an unsafe condition exists on the runway or taxiway, the incursion logic senses this condition and alerts an operator. Finally, the Display Interface function sends periodic display updates of all tracks to a separate display processor. The display processor updates the central processor's display surface and forwards the track data to the two other slave displays.

GSTARS is very useful in low-visibility conditions or for areas of the runway or taxiways that are not visible because of physical obstructions or limited sight distances, or when controller work load

is such that attention cannot be given to every segment of the ground operations. Without GSTARS, when unauthorized vehicles are on the runway or taxiway, air traffic controllers must see them, identify them, and then resolve the possible incursion as soon as possible, increasing voice communications load in the process. With GSTARS, the unauthorized vehicle sets off an alert that is sent to the tower automatically and immediately so that the controller can quickly identify and notify the involved vehicles to avoid a runway or taxiway incursion. Major benefits of GSTARS include:

- Increased situational awareness
  - All weather conditions
  - All airport vehicles types
  - All airport surfaces (concrete or asphalt)
- Cost-effective
  - Much less expensive than traditional ground radar
  - Price relates to airport size
- Scalable—number of intersections determines number of sensors
- Expandable—coverage can be increased as need increases
- Reliable
  - Automatic system health monitoring
  - No single point of failure
  - No moving parts

The FAA is currently completing the technology demonstration program at Long Beach Municipal Airport in Long Beach, California. This system integrates the approach radar's data along with loop data to better inform operators of aircraft location and thus provide increased airfield safety.

With integration of approach radar, the GSTARS system is able to predict when the runway will be occupied. This provides valuable information to the system for warning users of predicted runway occupancy to prevent runway incursions.

The original GSTARS program for MacDill AFB was planned to install a total of 50 inductive loops covering all taxiways, the apron area, and the runway. An interface to the approach radar was planned as well. Due to funding cuts, only 24 loops were installed and no radar interface was provided. The installed 24 loops provide coverage of Runway 04/22, all entry and exit taxiways A, B, C, D, E, and F to the runway, and Taxiway G, the taxiway parallel to Runway 04/22.

The Department of Defense installation has been completed at MacDill AFB in Tampa, Florida. This system incorporates a number of system improvements that increased reliability and usability of the basic system, including hard-wired power and fiber communications. Figure 2 provides a diagram of the GSTARS display that is installed at MacDill AFB.

GSTARS loop sensors were installed during nonpeak and evening hours in just a few weeks after the system design layout and approvals had been met. The loop sensors are embedded directly into the surface pavement material. The loops have proved to be very durable and have shown

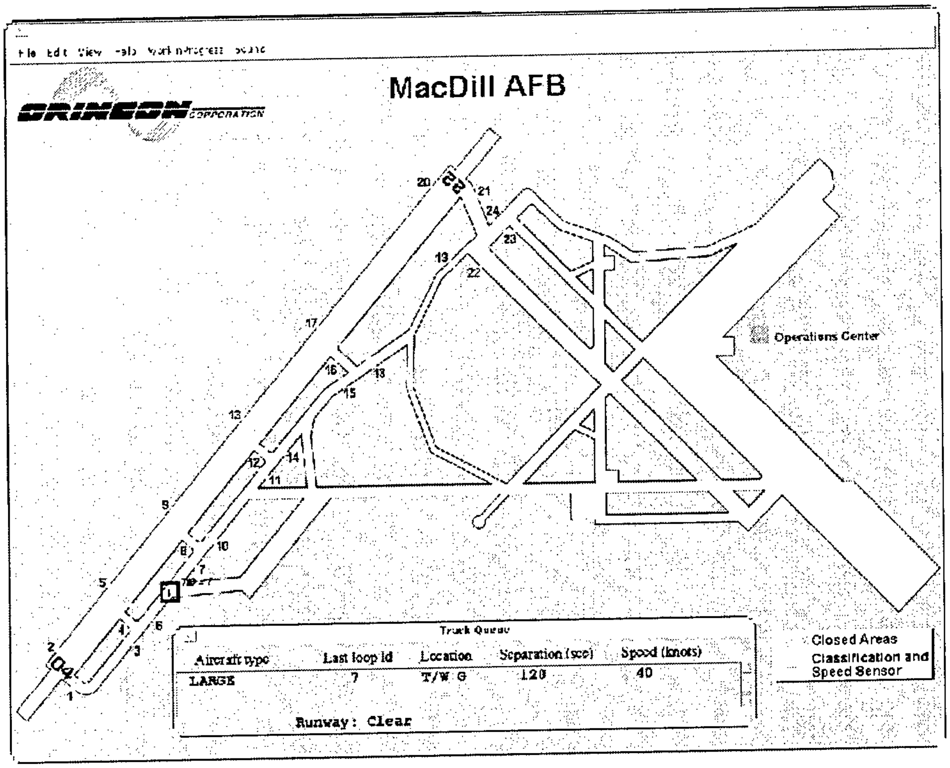

Figure 2. MacDill Display

no appreciable sign of wear over the years. GSTARS does not require any specialized building infrastructure and requires minimal space for the central processor and display(s). The display can be installed as a stand-alone terminal or mounted directly in a controller's console cabinet.

Slave displays provide valuable information to Base Operations and Base Command so that they have the proper awareness of aircraft and vehicle locations on the runways and taxiways and can better do their jobs.

Increased situational awareness is fast becoming an airport priority as air traffic and incursion problems increase at the nation's busiest airports. With the AGS/GSTARS solution, airports can effectively and automatically monitor airport surface traffic in all types of weather. This simple, cost-effective, and reliable alternative to ground-based radar systems can help our air traffic systems remain some of the safest in the world.

1.2 Frequently Asked Questions About AGS/GSTARS

1. Does saw-cutting damage the runway?
   Some of the loops that have been installed at Long Beach are nearly six years old. The loop edges are as they were from the original cut, and in particular, the corner cuts have shown no sign of breakup or fatigue and the sealant remains intact.

2. Will the sealant be ejected due to the heavy braking of large aircraft that causes asphalt creep?

   C5A aircraft land at Long Beach and there has not been any sealant ejected even in the summer.

3. What is the installation procedure when no trenching across airfield surfaces is required?

   At MacDill, directional drilling was used to install power and communications under taxiway and runway surfaces.

4. Will afterburner heat melt the sealant?

   Afterburner testing has not been done but the loop sealant was recessed approximately 1/8 inch to form a gap between the horizontal flow of hot gases to the surface of the sealant.

5. Some runways and taxiways have a microsurface coating. How will loop installation affect this surface?

   Microsurface Technology, the installer of the microsurface at MacDill, indicated that the material has the properties similar to asphalt, and it can be cut and sealed just as you would asphalt with no difference in wear or durability.

6. Will the loop field affect aircraft/navigation electronics or munitions?

   We have not seen any evidence that the field affects other electronics. The field is less than 1/10 of the field strength of the earth's magnetic field. F16 fighters loaded with munitions for bombing practice crossed the loops at MacDill and there were no problems reported.

7. How do fuel and oils affect the epoxy?

   Since the first loops were installed in November/December 1998, ORINCON has seen no wear due to fuel or oil spills.

8. How does lightning affect the system?

   The IVS-2000 has approximately 200 volts of surge protection on the sensor input and the power is installed 36 inches under the surface at MacDill. The communications are via fiber optic cable that will not be affected. To improve lightning protection to the electronic equipment in each cabinet, ARINC will install power conditioners in each of the seven cabinets.

1.3 GSTARS Components

GSTARS consists of three distinct components:

1. Isolated and distributed loop sensors and electronics on the airfield.
2. Fiber optic local area network (LAN) that links the field electronics with the central computer and slave computers.
3. The central processing computer located in Base Command with slave computers located in the Tower and Base Operations.

The GSTARS detection electronics system, the IVS-2000, hosts the interface to the physical loop for sensing aircraft or ground vehicles passing over the loop. The IVS-2000 also has software for detecting a loop crossing, classifying the generated signature of the aircraft or ground vehicle, estimating the speed, and communicating this information to the central computer in Base Command via the fiber optic LAN (Figure 3).

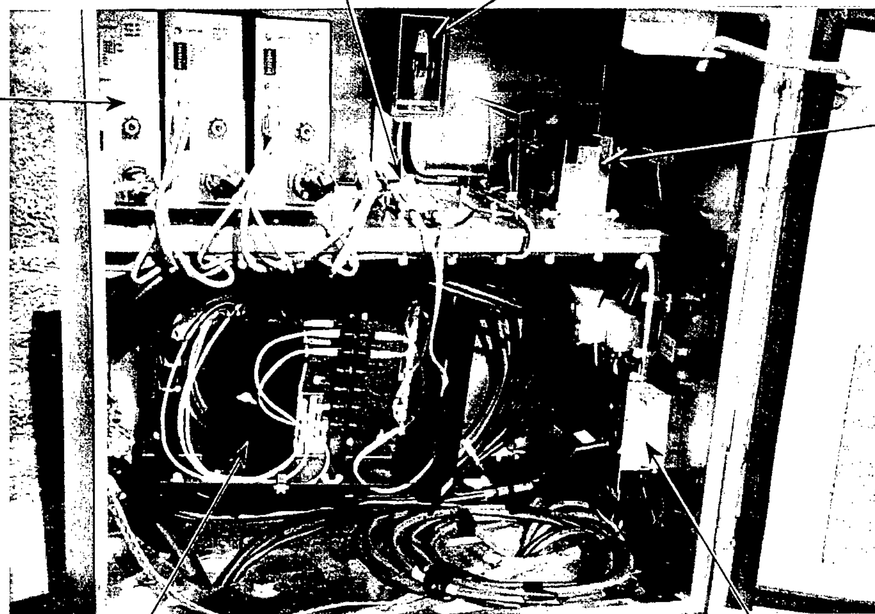

Figure 3. Cabinet Layout Showing Power and Fiber Optic Connections

The IVS-2000 signal is directed to an RS-232 to fiber optic converter that is sent to Building 1194, where a fiber optic multiplexer multiplexes the 24-loop data to the central computer located in Building 54 (Base Command) (Figure 4). Building 1194 is also the source of 480 VAC power for the field electronics.

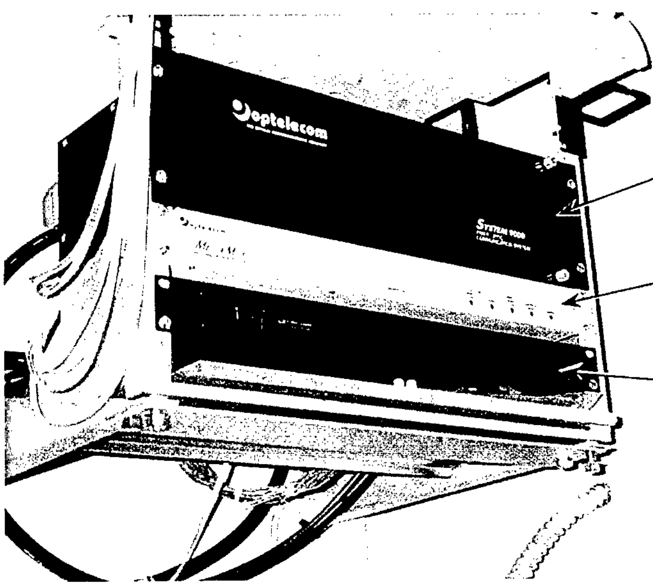

Figure 4. Building 1194 Fiber Optic Multiplexer

The host central computer interfaces to the airfield through communications software and the 32-channel serial smart interface (Figure 5) that communicates with the fiber optic multiplexer in the LAN. A 56K modem is provided for communication with outside computers located at ORINCON to update software and gather training data. The central computer also communicates with two slave computers, one located in the Tower and the other located in Base Operations.

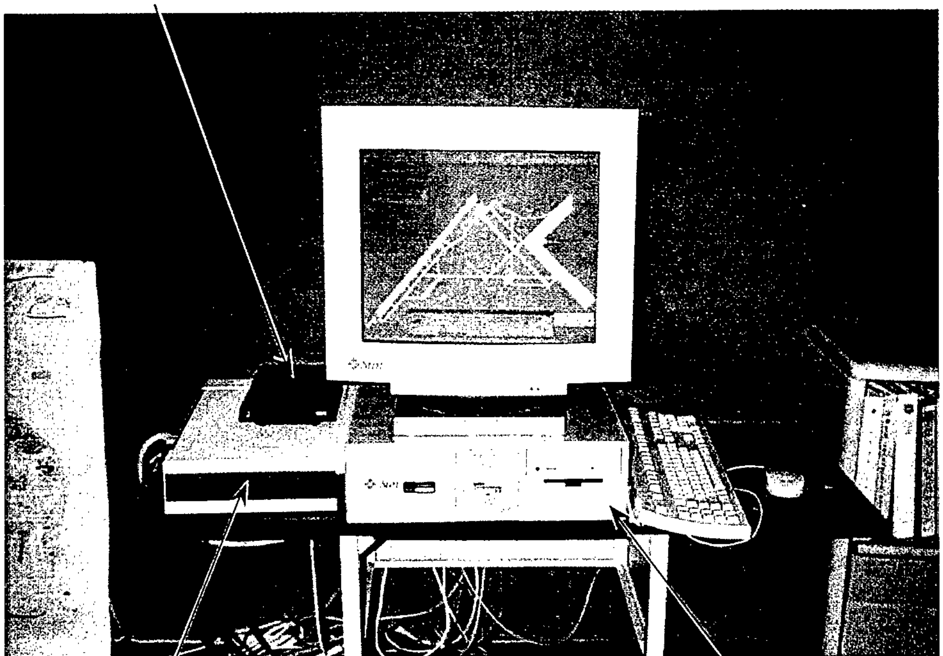

Figure 5. Serial Smart Interface to the Field Electronics via Multiplexer

This communication is via the MacDill fiber optic network. The Tower interface is via single-mode fiber and Base Operations is via multimode fiber. Two 100 base T to single-mode optical fiber converters are provided to make these connections (Figure 6). Base Operations is on MacDill's multimode fiber optic system; thus, a single-mode to multimode converter is provided in the Hanger 2 Information Transfer Node (ITN) to provide signal compatibility between Base Command and Base Operations (Figure 7).

1.4 Installation of Loops

GSTARS runway loops were installed during the two-week period when the MacDill runway was closed. Other loops were installed in conjunction with repaving operations. At Long Beach Airport, loops were installed at night when the airport was closed. Figures 8 through 10 show how the loops were installed. First, a saw-cutting machine makes the ¼ inch by 1¾ inch deep cut

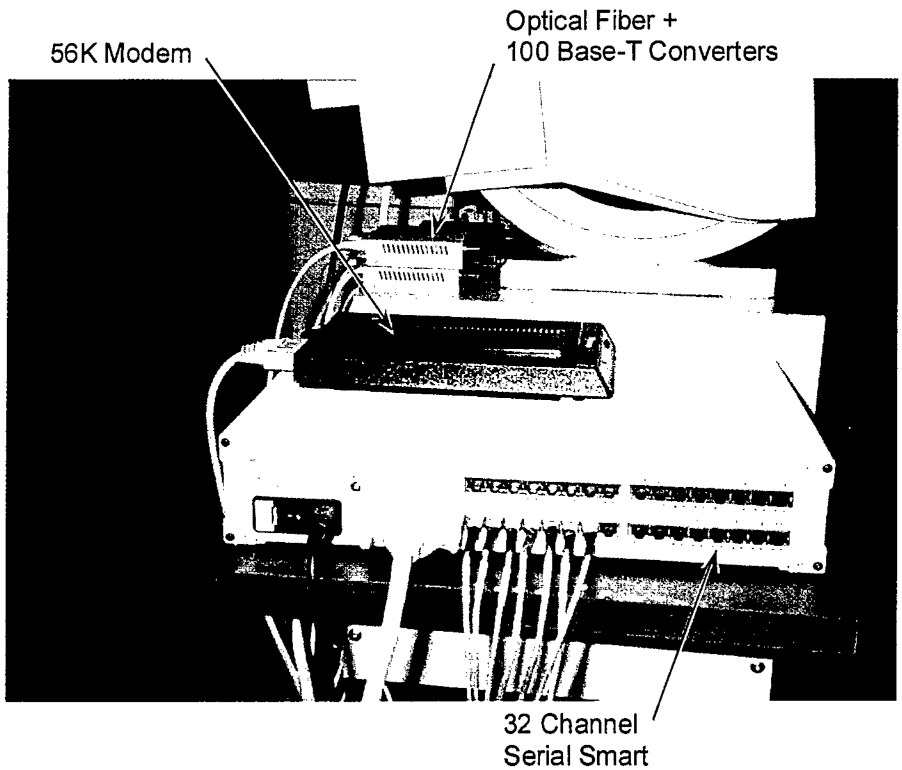

Figure 6. 100 Base T to Single-Mode Fiber Converters

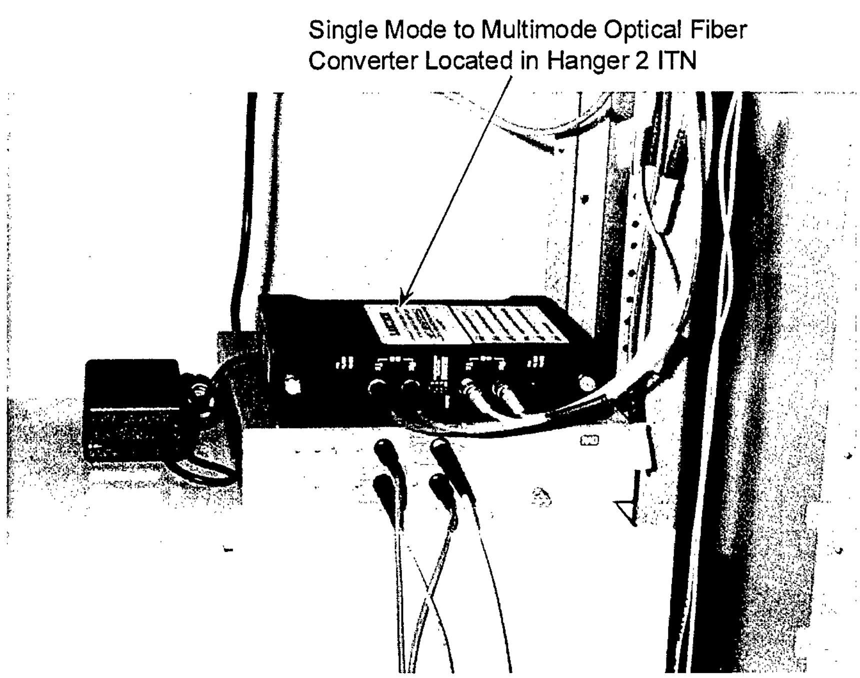

Figure 7. Single-Mode to Multimode Fiber Optic Converter in Hanger 2 ITN

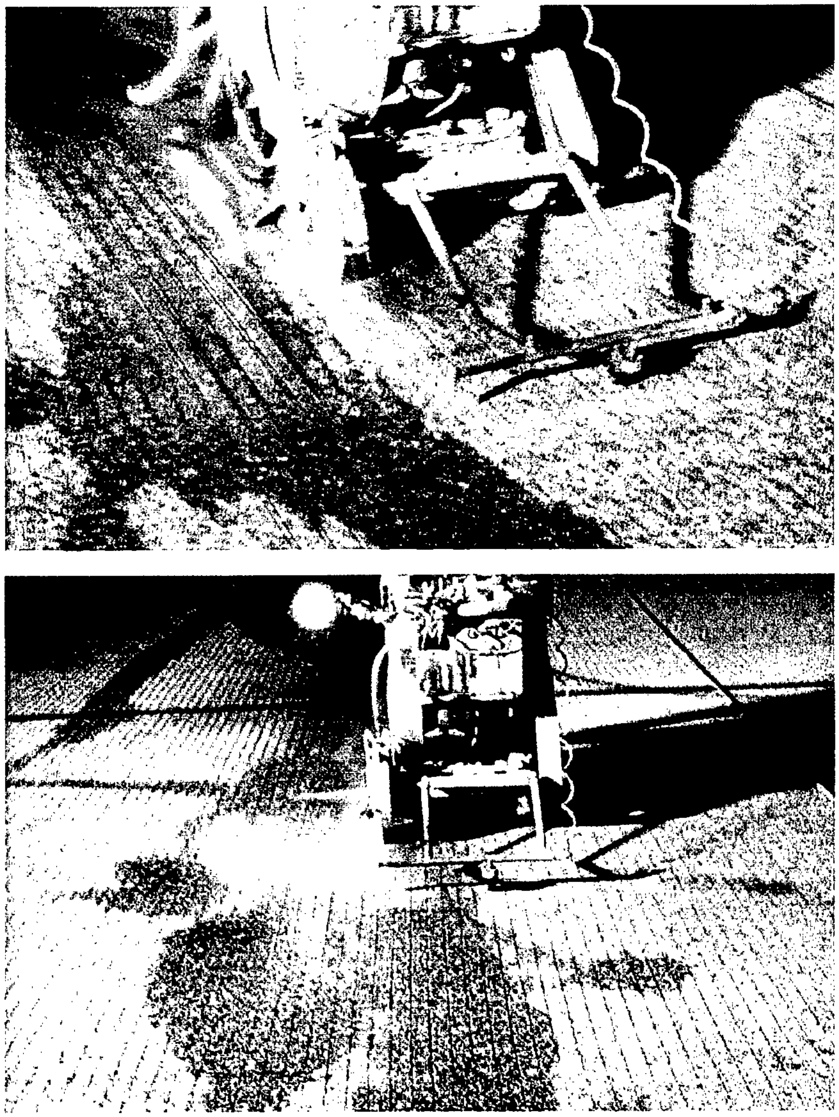

Figure 8. Saw-Cutting the Runway/Taxiway

in the pavement for the 10 x 75 foot taxiway or 10 x 150 foot runway loop (Figure 8). The saw-cut material (foreign object debris, or FOD) is then thoroughly removed by washing the cut and vacuuming (Figure 9). (All FOD is completely removed from around the runways and taxiways.) Three turns of sensor wire is then placed in the saw-cut space and a styrofoam backer rod is placed over the sensor wires and tamped into place to seal the wires into place. Finally, the sealer is placed in the saw-cut over the backer rod (Figure 10). The sealant is dry to the touch in about 30 minutes and thoroughly dry in a few hours.

1.5 Features and Benefits

Increased Situational Awareness. Air traffic controllers, Base Operations, and Base Command personnel will know where aircraft and ground vehicles are located on taxiways and runway

Figure 9. The Saw-Cut is Completely Cleaned and Vacuumed

surfaces by aircraft and vehicle type in all weather conditions. GSTARS has the capability to fuse air surveillance radar and other sensors with loop sensor data to provide complete air and ground coverage, as demonstrated by the installation at Long Beach Airport. Airport safety is also enhanced by the inclusion of incursion logic implemented to alert operators to unsafe operations on the runway.

Aircraft and Ground Classification. GSTARS provides air traffic controllers, Base Command, and Base Operations with a departure queue by aircraft type. Safety intervals for individual aircraft type can be shown, thereby reducing voice communications. Aircraft classification provides an excellent technical advantage in associating sensor measurements within the Data Fusion/Tracking system.

Affordable. A GSTARS system costs 10 to 15 times less than an ASDE3 radar system. Price also scales with the airport size.

Figure 10. The Sensor Wire is Placed in the Saw-Cut, a Styrofoam Backer Rod is Installed to Hold the Wire in Place, and Sealant is Applied

Scalable and Expandable. The number of runways, taxiways, and runway and taxiway intersections determines the number of sensors required. The GSTARS design is expandable, so surface monitoring coverage can increase in phases over time as needs grow.

Reliable. GSTARS works under all weather and visibility conditions. The sensors and electronics meet rigorous standards. System health is automatically reported. The host Sun computer continuously monitors the health of the field sensor electronics and the field sensor electronics continuously monitor the health of the loop sensors. If a failure is detected, it is reported to the operator. GSTARS has no moving parts.

Fast and Nonintrusive Installation. GSTARS runway loops were installed during the two-week period when the MacDill runway was closed. The taxiway loops were installed in conjunction with repaving operations. In some cases, pave-over loops were installed. At other times, loops were cut into the taxiways, depending on the how much taxiway resurfacing was required. GSTARS computers and displays were installed in areas designated by the base and required minimal space.

Isolated and Distributed Sensors. GSTARS consists of isolated and distributed sensors. Therefore, no single sensor point of failure exists, as is experienced in complex radar systems. This architecture also enhances system reliability and dependability.

Operability. GSTARS is a simple system to use. Once the system is turned on, the system displays the airfield ground traffic and alerts operators to unsafe events. The operators require little or no interaction with the system. Thus, a highly operable system is provided.

1.6 Applications

Air Traffic Control Tower

- GSTARS provides controllers with occupancy status of critical airport taxiway and runway segments. GSTARS also alerts operators to unsafe operations on runways and taxiways in all types of weather.
- GSTARS can be used to increase airfield security by providing loop sensors at uncontrolled entrances. Base Operations can be alerted if an intruder enters the airfield.
- Loop sensors can be placed around aircraft parked on the ramp area. If a vehicle crosses the looped area, Base Operations can be alerted so that the proper security personnel can be directed to intercept the intruder.
- GSTARS has the capability to provide controllers with departure queue by aircraft type so safety intervals are maintained. As a result, voice communications between the tower and aircraft are reduced.
- GSTARS information can be used to control airport lighting.
- GSTARS can be used to augment other operational systems, such as ground search radar, that have multipath and shadowing problems or to provide a more complete picture to controllers by combining approach radar data with ground data from the loop system.

- Combining the approach radar data with loop sensor data in the incursion logic can provide enhanced safety.

User

- GSTARS can provide runway occupancy alerting to arriving aircraft for towered and untowered airports.
- GSTARS can be installed at an uncontrolled airfield that is in the flight path of another airfield. Departure and arrival information from the uncontrolled airport can be reported/displayed to the controller in the controlled airfield. This information will help the air traffic controller provide safe arrival/departure instructions to aircraft departing/arriving at his airfield.
- GSTARS can provide information that can be used for taxiway guidance to and from runways and ramps, eliminating the need for follow-me vehicles, and combined with runway lighting, can efficiently move departing aircraft from the ramp to the runway and arriving aircraft from the runway to the ramp.

Airport Operations

- GSTARS can provide a detailed airport and runway use record that could replace or supplement the controller-generated "strips" reported by the controllers. Additionally, vehicle use traffic records on taxiways can be generated.

1.7 GSTARS Contractors

ARINC Incorporated and ORINCON Technologies Incorporated (OTI) have entered into a joint marketing and teaming agreement to market, install, and support the Ground Safety Tracking and Reporting System (GSTARS) to civil airports throughout the U.S. and in the international marketplace. The two companies have produced and installed a GSTARS for the Department of Defense, under the Airfield Ground Safety (AGS) initiative, at MacDill Air Force Base.

Appendix A

System User Manual
for
Ground Safety Tracking and Reporting System
(GSTARS)

AIRFIELD GROUND SAFETY PROGRAM

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1.0 INTRODUCTION

The MacDill Air Force Base (AFB) Loop Detection System has been designed so that the operators can use the system with little instruction. Thus, this guide is designed primarily to provide supplemental and background information on the system's use. This guide is divided into four sections. Section 2.0 reviews the operational concept behind the Loop Detection System. Section 3.0 explains the general features of the system. Section 4.0 describes the basic operation of the device and the detailed features and usage scenarios for each of the current modes of operation. Section 5.0 is a brief tutorial, including troubleshooting and maintenance information.

2.0 OVERVIEW

The MacDill Loop Detection System delivers state-of-the-art runway and taxiway detection of aircraft and vehicles and has been designed to alert operators of unsafe operations. The system will also detect when a vehicle enters and leaves the system.

The system being installed at MacDill AFB consists of 24 inductive loops, which are installed in the runways and taxiways as shown in Figure 1. Associated with these loops are seven cabinets, which house the electronics (IVS-2000) that detect and classify the signatures of aircraft and ground vehicles that pass over the loops. The IVS-2000 sends aircraft detection data along with the aircraft classification to the central computer (a Sun workstation) located in the Base Command. This computer houses the communications channel control, tracking function, incursion logic, and display generator. Also within the central computer is the necessary logic to drive the electronics and display function of the repeater display located in the Tower and Base Operations (Dell computers).

3.0 KEY FEATURES

Figure 2 shows the end-to-end system that performs the detection, classification, tracking, incursion logic, and display of detection results, aircraft movements, and incursion alerts. The left side of the figure shows in functional flow form the processing performed by each IVS-2000, while the right side of the figure shows the processing functions and flow in the host Sun computer and accompanying slave displays.

The following paragraphs summarize the processing that takes place in the IVS-2000 and host computer.

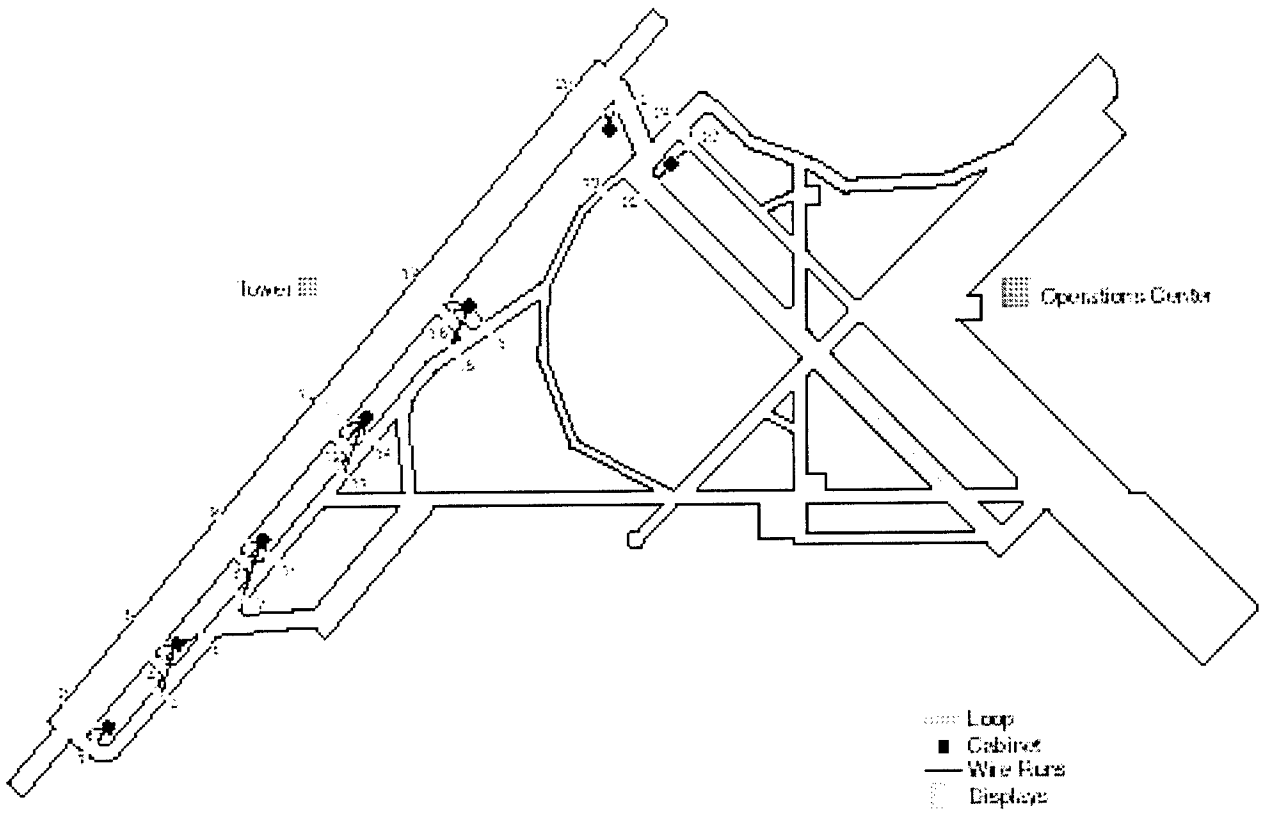

Figure 1. MacDill Airfield Loop and Cabinet Layout

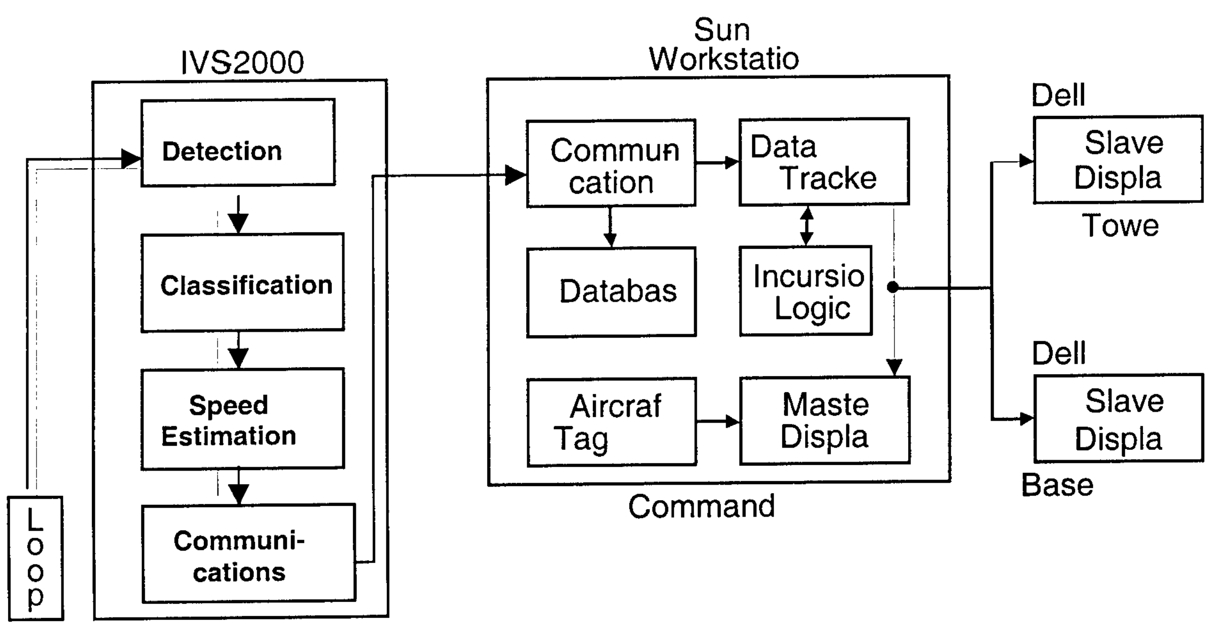

Figure 2. System Functional Overview for Detection, Classification, Tracking, and Display

As an aircraft passes over a loop, the steady-state inductance of that loop changes due to the introduction of metal into the inductive field generated by the loop. The IVS-2000 hardware and software detect this change in inductance. The detection software determines the start and end of the detection, and then converts the signature into a vector used by the classifier. The classifier attempts to classify the detection as an aircraft (small, large, or heavy) or as a ground vehicle.

The host computer continuously polls each IVS-2000 and when an IVS-2000 makes a detection, it sends the signature, speed, classification, and classification confidence to the host computer located in Base Command.

When an aircraft detection and its associated attributes are received, they are first written to a disk file, and then sent on to the Data Fusion/Tracker. The Data Fusion/Tracker attempts to associate an incoming detection with an existing aircraft track of the same type. If an association is made, the existing track is updated and output to the operational display, along with all of its track-level information. If, after applying the association rules, no association can be made, a new track is formed and sent to the operational display along with all of its track-level information.

If there are existing tracks and no detection, the Data Fusion/Tracker predicts the existing tracks from their current position to new positions as a function of each track's velocity and predict time interval.

The three operational displays (17-inch display in the Tower, 17-inch display in Base Operations, and 20-inch display in Base Command) depict the runways, taxiways, and ramp areas at MacDill Air Force Base. Additionally, the locations of the 24 installed loops are displayed. The updated and predicted tracks are displayed as the data is received from the Data Fusion/Tracker. The track number is shown next to each track symbol. The color of the track symbol indicates the general classification of the aircraft: small (green), large (blue), heavy (yellow), unknown (red). Vehicles are shown in red.

Sound is also used to alert the operator of an unsafe condition. Whenever a vehicle first enters on the taxiway or runway, an audible tone will be generated and an all-clear message will be generated when the vehicle leaves the system.

4.0 OPERATION

This section describes the end-to-end running of the loop detection system on the Sun workstation located in Base Command. Figure 2 shows the functionality performed by the system.

This phase of the effort is primarily a proof-of-concept system to demonstrate that inductance loop technology can classify aircraft that are taxiing, arriving, and departing. The system will also classify ground vehicles entering the taxiway and runway.

The steps involved in running the system are shown in Figure 3.

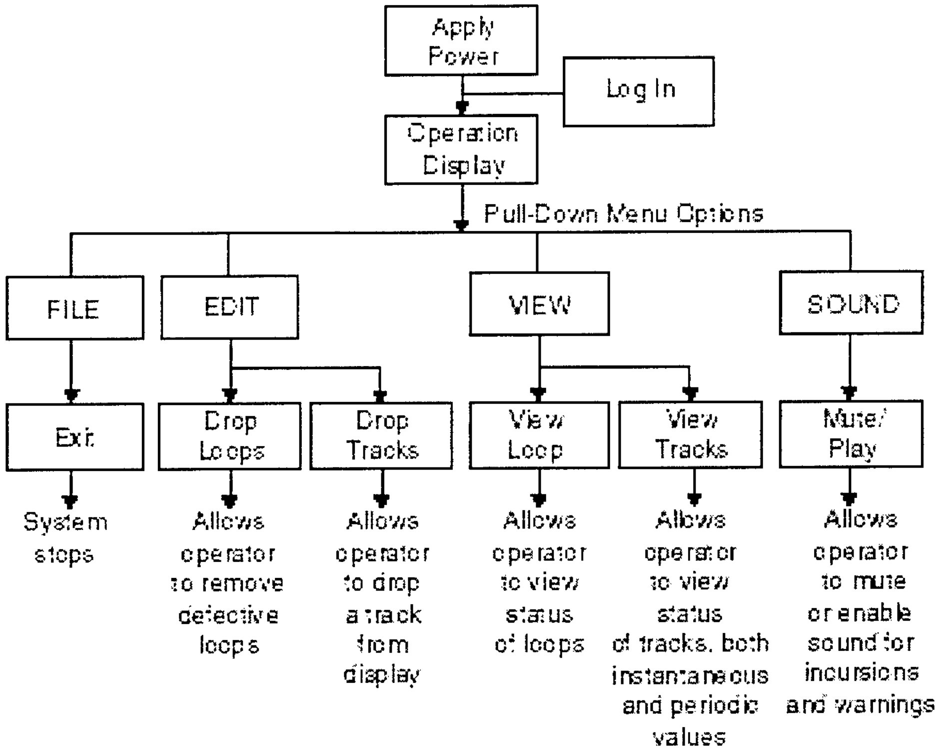

Figure 3. Flow Diagram of How to Run the System at MacDill Air Force Base

4.1 Initiating System Operation

The following steps are required to run the system. There are three computers in the AGS system: the host computer located in the Base Command Post, a display computer in Base Operations, and a display computer in the Tower cab. All three computers must be powered on and operational to run the system. The system is started from the Base Command Post Main Computer. When running the AGS system from Base Command, only users on that computer can delete loops and tracks.

4.1.1 Operating From Base Command

From the AGS Main Computer in Base Command, in the logon box, enter **ags**, then return. In the password box, enter **ags1**, then return. After a period of about 20 seconds, five windows will appear. The following five steps may be run from any window. The order of the five steps is important and must be followed exactly.

Select one of the windows (typically the upper right-hand window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

cd macdill/exec

then return. When the prompt (>) returns, type

incur_mht_loop_main

Do not enter the return key yet.

Move the mouse cursor into another window (typically the lower right window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

cd comms_exec

then return. When the prompt (>) returns, type

comms

Do not enter the return key yet.

Move the mouse cursor into another window (typically the lower left window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

cd macdill/display

then return. When the prompt (>) returns, type

make runhost

Do not enter the return key yet.

Move the mouse cursor into another window (typically the window just above the lower left window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

telnet macdillops

then return. You now must log on the Base Operations Computer. The procedure is identical to the one used to log on the Main Computer. The user name and password are identical to the Main Computer: **ags, ags1**. When the prompt (>) returns after logging in, type

setenv DISPLAY macdillops:0.0 (these are zeroes)

then return. When the prompt (>) returns, type

cd macdill/display

then return. When the prompt (>) returns, type

make runpc1

Do not enter the return key yet.

Move the mouse cursor into another window (typically two windows above the lower left window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

telnet macdilltower

then return. You now need to log on the Tower Computer. The procedure is identical to the one used to log on the Main Computer and the MacDill Base Operations Computer. The user name and password are identical to the Main Computer: **ags**, **ags1**. When the prompt (>) returns after logging in, type

setenv DISPLAY macdilltower:0.0 (these are zeroes)

then return. When the prompt (>) returns, type

cd macdill/display

then return. When the prompt (>) returns, type

make runpc2

Do not enter the return key yet.

Once all of the commands have been typed in, you can now start running the system by going back and entering the return key. Now go back to the first window, the one where **incur_mht_loop_main** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter. Now move the mouse cursor to the second window, the one where **comms** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter. Now move the mouse cursor to the third window, the one where **make runhost** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter. Now move the mouse cursor to the fourth window, the one where **make runpc1** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter. Now move the mouse cursor to the fifth window, the one where **make runpc2** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter.

The display in all three locations should come up. Aircraft and ground vehicle tracks will be displayed as they are detected on the airfield.

Alternately, the system may be started from either Base Operations or the Tower cab location. If the users in Base Operations are to have control of deleting loops and tracks, then the AGS system should be run from Base Operations. If the users in the Tower cab are to have control of deleting loops and tracks, then the AGS system should be run from Tower cab.

4.1.2 Operating From Base Operations

The Base Operations Computer will have full control of the AGS system. All three computers must be powered on and operational to run the system. To run the AGS system from Base Operations, follow these commands.

From the Base Operations Computer, in the logon box, enter **ags**, then return. In the password box, enter **ags1**, then return. After a period of about 20 seconds, five windows will appear. The following five steps may be run from any window. The order of the five steps is important and must be followed exactly.

Select one of the windows (typically the upper right-hand window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

telnet ags1

then return. You now must log on the Base Command Main Computer. The procedure is identical to the one used to log on the Base Operations Computer. The user name and password are identical to the Base Operations Computer: **ags, ags1**. When the prompt (>) returns after logging in, type

cd macdill/exec

then return. When the prompt (>) returns, type

incur_mht_loop_main

Do not enter the return key yet.

Move the mouse cursor into another window (typically the lower right window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

telnet ags1

then return. You now must log on the Base Command Main Computer. The procedure is identical to the one used to log on the Base Operations Computer. The user name and password are identical to the Base Operations Computer: **ags, ags1**. When the prompt (>) returns after logging in, type

cd comms_exec

then return. When the prompt (>) returns, type

comms

Do not enter the return key yet.

Move the mouse cursor into another window (typically the lower left window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

cd macdill/display

then return. When the prompt (>) returns, type

make runhost

Do not enter the return key yet.

Move the mouse cursor into another window (typically the window just above the lower left window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

telnet ags1

then return. You now must log on the Command Main Computer. The procedure is identical to the one used to log on the Base Operations Computer. The user name and password are identical to the Base Operations Computer: **ags**, **ags1**. When the prompt (>) returns after logging in, type

setenv DISPLAY ags1:0.0 (these are zeroes)

then return. When the prompt (>) returns, type

cd macdill/display

then return. When the prompt (>) returns, type

make runpc1

Do not enter the return key yet.

Move the mouse cursor into another window (typically two windows above the lower left window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

telnet macdilltower

then return. You now need to log on the Tower Computer. The procedure is identical to the one used to log on the Main Computer and the MacDill Base Operations Computer. The user name and password are identical to the Base Command Computer: **ags**, **ags1**. When the prompt (>) returns after logging in, type

setenv DISPLAY macdilltower:0.0 (these are zeroes)

then return. When the prompt (>) returns, type

cd macdill/display

then return. When the prompt (>) returns, type

make runpc2

Do not enter the return key yet.

Once all of the commands have been typed in, you can now start running the system by going back and entering the return key. Now go back to the first window, the one wherer **incur_mht_loop_main** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter. Now move the mouse cursor to the second window, the one where **comms** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter. Now move the mouse cursor to the third window, the one where **make runhost** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter. Now move the mouse cursor to the fourth window, the one where **make runpc1** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter. Now move the mouse cursor to the fifth window, the one where **make runpc2** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter.

4.1.3 Operating From Tower Cab

The Tower Cab Computer will have full control of the AGS system. All three computers must be powered on and operational to run the system. To run the AGS system from the Tower Cab Computer follow the following commands.

From the Tower Cab Computer, in the logon box, enter **ags**, then return. In the password box, enter **ags1**, then return. After a period of about 20 seconds, five windows will appear. The following five steps may be run from any window. The order of the five steps is important and must be followed exactly.

Select one of the windows (typically the upper right-hand window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

telnet ags1

then return. You now must log on the Base Command Main Computer. The procedure is identical to the one used to log on the Tower Cab Computer. The user name and password are identical to the Tower Cab Computer: **ags**, **ags1**. When the prompt (>) returns after logging in, type

cd macdill/exec

then return. When the prompt (>) returns, type

incur_mht_loop_main

Do not enter the return key yet.

Move the mouse cursor into another window (typically the lower right window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

telnet ags1

then return. You now must log on the Base Command Main Computer. The procedure is identical to the one used to logon the Tower Cab Computer. The user name and password are identical to the Tower Cab Computer: **ags**, **ags1**. When the prompt (>) returns after logging in, type

cd comms_exec

then return. When the prompt (>) returns, type

comms

Do not enter the return key yet.

Move the mouse cursor into another window (typically the lower left window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

cd macdill/display

then return. When the prompt (>) returns, type

make runhost

Do not enter the return key yet.

Move the mouse cursor into another window (typically the window just above the lower left window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

telnet ags1

then return. You now must log on the Base Operations Computer. The procedure is identical to the one used to log on the Tower Cab Computer. The user name and password are identical to the Tower Cab Computer: **ags**, **ags1**. When the prompt (>) returns after logging in, type

setenv DISPLAY ags1:0.0 (these are zeroes)

then return. When the prompt (>) returns, type

cd macdill/display

then return. When the prompt (>) returns, type

make runpc2

Do not enter the return key yet.

Move the mouse cursor into another window (typically two windows above the lower left window) by moving the mouse cursor into the window and click the left mouse button. At the (>) prompt type

telnet macdillops

then return. You now need to log on the Base Operations Computer. The procedure is identical to the one used to log on the Tower Cab Computer and the MacDill Base Command Main Computer. The user name and password are identical to the Tower Cab Computer: **ags**, **ags1**. When the prompt (>) returns after logging in, type

setenv DISPLAY macdillops:0.0 (these are zeroes)

then return. When the prompt (>) returns, type

cd macdill/display

then return. When the prompt (>) returns, type

make runpc1

Do not enter the return key yet.

Once all of the commands have been typed in, you can now start running the system by going back and entering the return key. Now go back to the first window, the one where **incur_mht_loop_main** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter. Now move the mouse cursor to the second window, the one where **comms** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter. Now move the mouse cursor to the third window, the one where **make runhost** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter. Now move the mouse cursor to the fourth window, the one where **make runpc1** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter. Now move the mouse cursor to the fifth window, the one where **make runpc2** was typed in, by moving the mouse cursor to that window, then press the left mouse button and then enter.

Primary Display

Figure 4 shows a map of MacDill AFB as seen on the operational display. At the upper left portion of the operational display is the pull-down options window. The options **File**, **Edit**, **View**, and **Sound** are shown.

The Track Queue window at the bottom of the main window in Figure 4 shows the active tracks in the AGS system. Aircraft type, last loop crossed, location, and speed are shown for all active tracks. The number preceding the aircraft type is the Track ID and corresponds to the TID on the main display.

4.2 File Selection

There is one **File** selection option at this stage of the project: **Exit**. When the system is turned on, the **Operational** display is generated for the operator's use.

When **Exit** is selected using the mouse, the system is stopped.

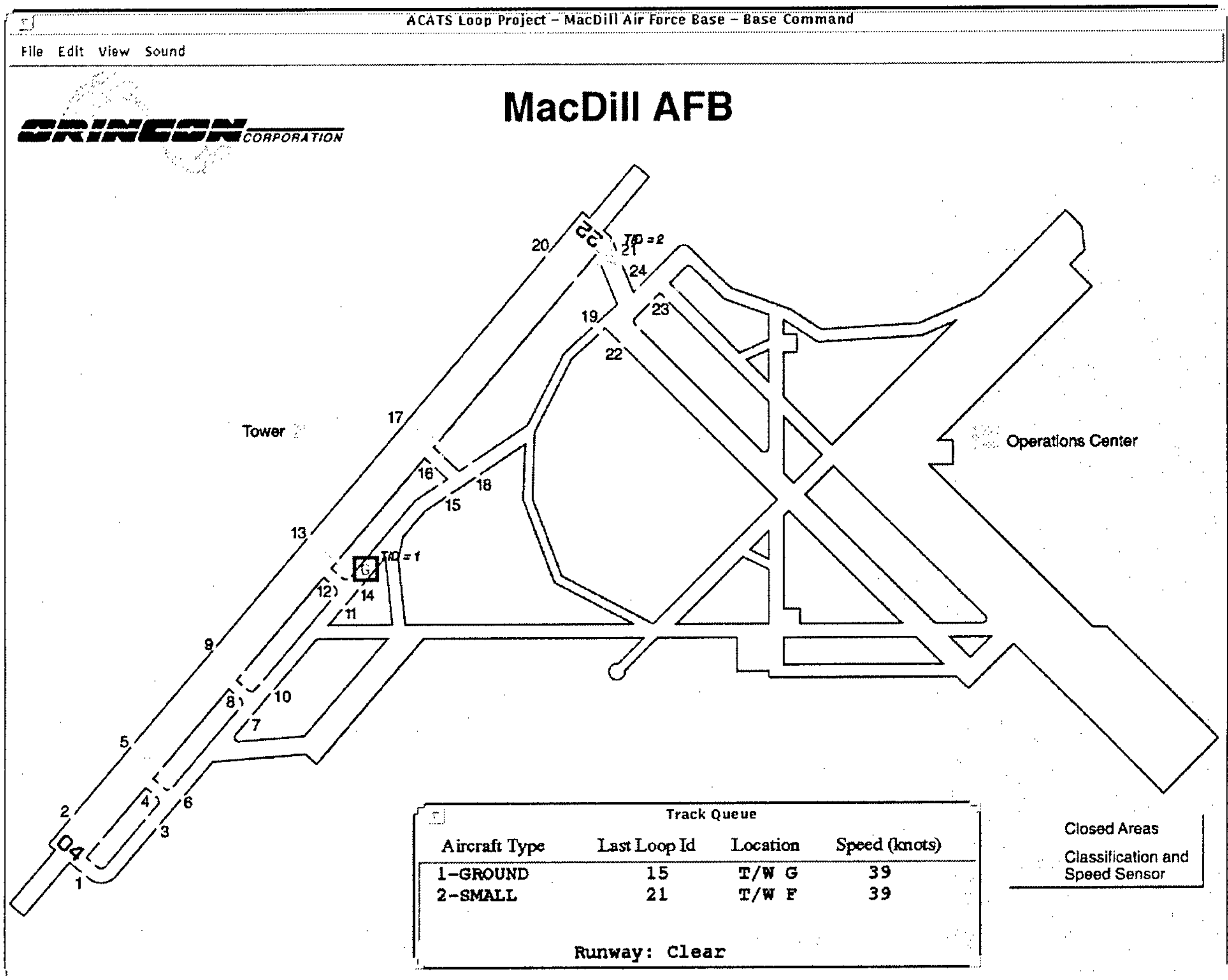

Figure 4. Display of MacDill Air Force Base Layout and Loop Locations

4.3 Edit Selection

The Edit selection shows four options: **Drop Loops** and **Drop Tracks**. These options allow the operator to remove loops and tracks from the system.

4.3.1 Drop Loops/Reactivate Loops

When **Drop Loops** is selected, a display list window pops up with a list of loops. By selecting one of the loop numbers listed and then selecting **Drop**, that loop is removed from processing by the Data Fusion/Tracker. The loop on the Display remains, but it is inactive. Figure 5 shows an example of the Drop Loop window.

4.3.2 *Drop Tracks*

This function allows an operator to drop a track. When the window appears with all the tracks listed, the operator highlights the track to be dropped using the mouse; the track is dropped when the operator presses the drop box next to the highlighted track using the mouse. This function is shown in Figure 6.

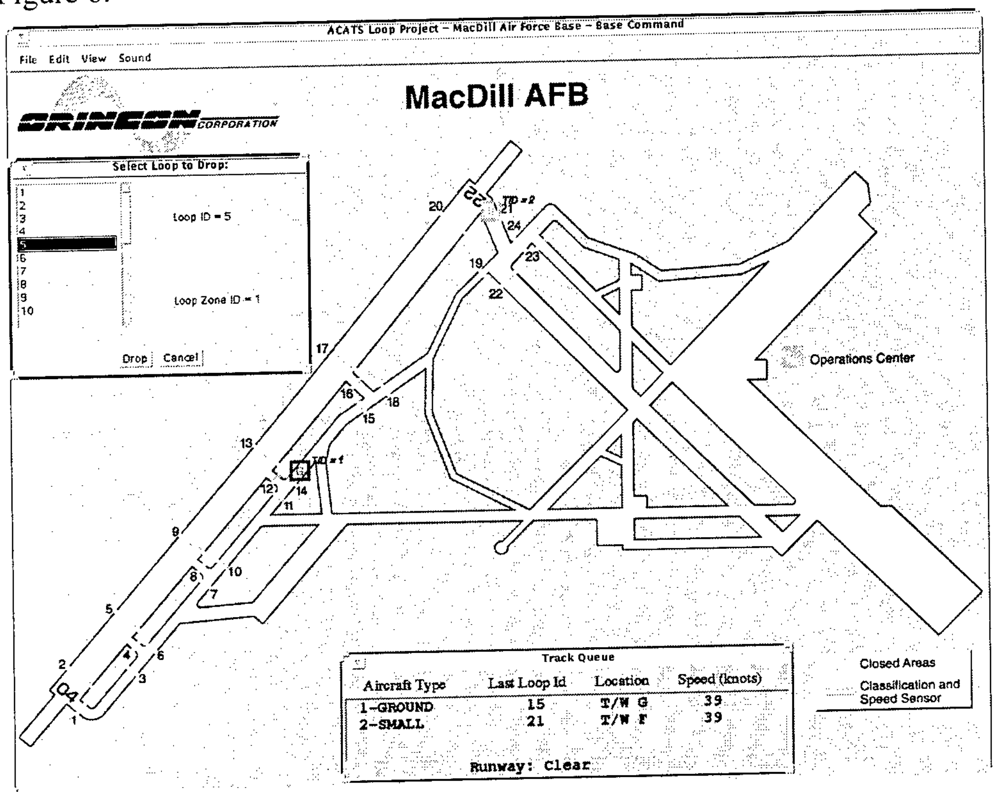

Figure 5. Drop Loop Window

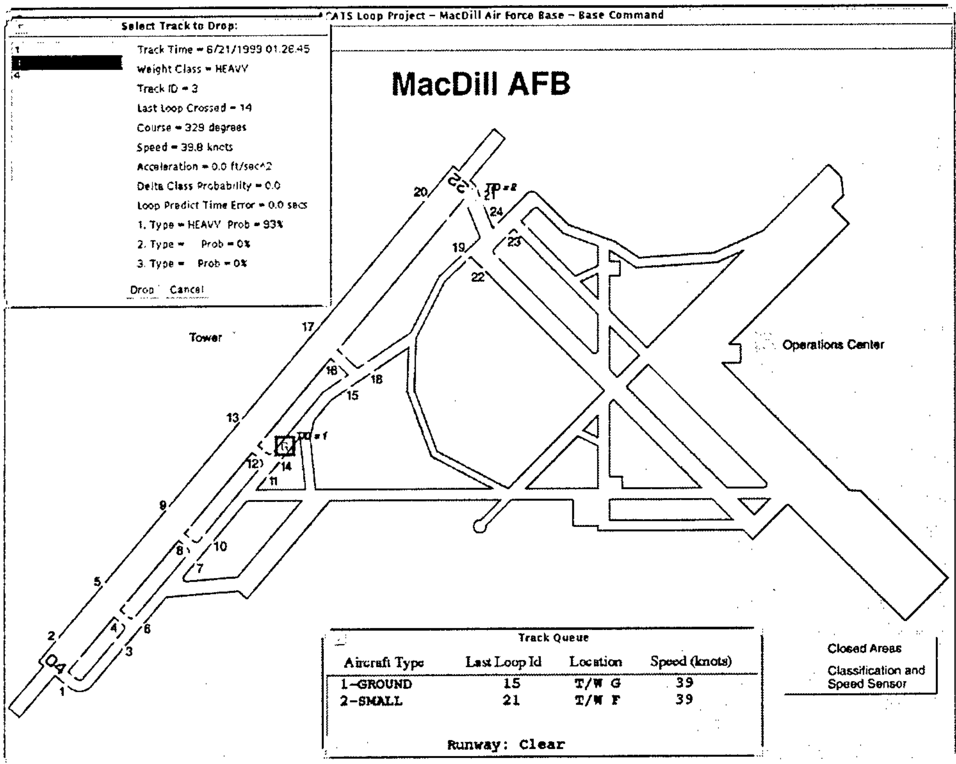

Figure 6. Drop Track Window

4.4 View Selection

The **View** selection shows two options: **Loops** and **Tracks**. This option is used to get status information on any of the any of the 24 loops or active tracks.

4.4.1 Loop View

When **Loop View** is selected, the display window shows the location of the loops, as shown in Figure 7.

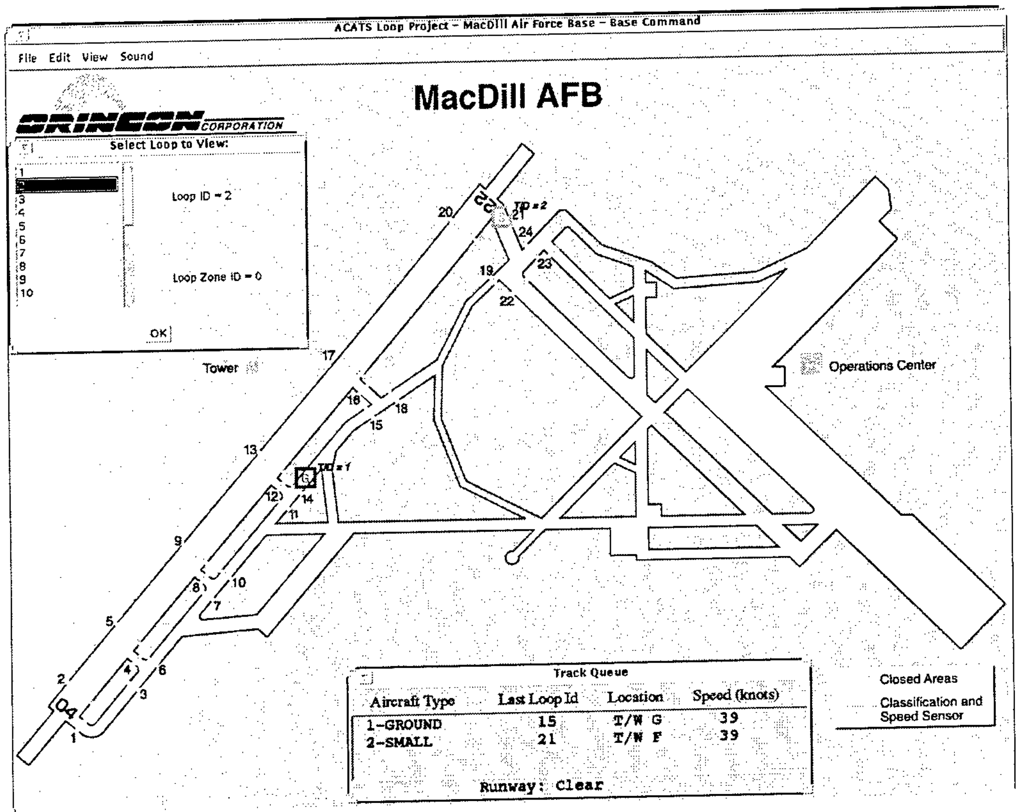

Figure 7. Loop View Window

4.4.2 Track View Selection

When **Tracks** is selected, a display list window pops up showing a list of existing tracks. By selecting one of the Track IDs, track and metric information on that track is displayed. Figure 8 shows an example for Track 2. The **Close** button is used to close this window.

The following information is displayed in the track window:

- Track Time: Time of the current predicted track position. If the aircraft has just been detected at a loop, it is the actual time of detection.
- Weight Class: This field indicates the weight class: Ground Vehicle, Small, Large, Heavy, or Unknown.

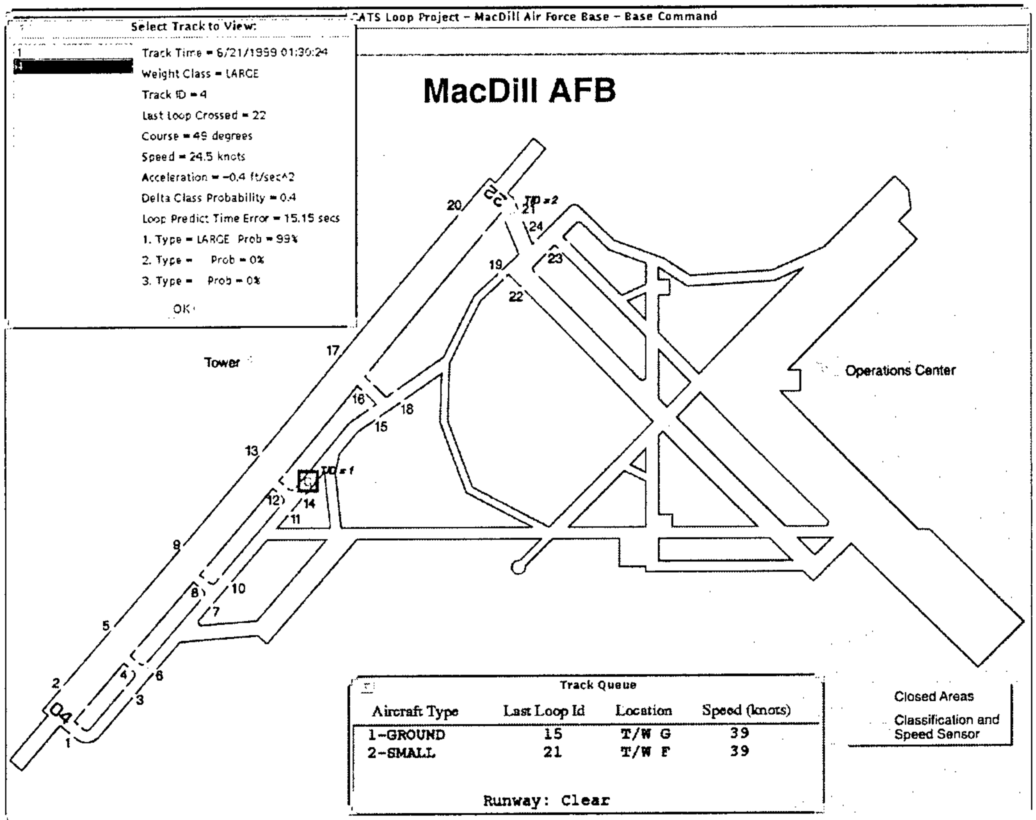

Figure 8. Track View Window

- Track ID: The Data Fusion/Tracker-assigned track number.
- Last Loop Crossed: Loop number of the last loop on which this aircraft was actually detected.
- Course: Course in degrees from north.
- Speed: Speed in knots.
- Acceleration: Acceleration in ft/sec2.
- Delta Class Probability: Improvement in confidence of classification from first loop detected on to the last loop detected on.
- Loop Predict Time Error: Difference between the time the Data Fusion/Tracker predicted the aircraft to arrive at the next loop and the time it actually arrived, in seconds.
- Type and probability: The top three aircraft classifications and the probability that the aircraft is that type.

4.5 Sound

4.5.1 Audio Level Control

This function allows the operator at any display to mute/play the audio level for any alert. A mute/play control is provided for the alerts. Using the mouse, the operator selects play/mute under the sound pull-down menu item.

5.0 TROUBLESHOOTING

Using the system block diagram shown in Figure 9, proceed with the following troubleshooting steps.

1. If it appears that the system is not communicating with any of the loops, the problem is most likely in the multiplexer/demultiplexer located either in Base Command or in Building 1194. First check to see that the multiplexer/ demultiplexer unit power cord is plugged into a 120Vac outlet, and the power switch is in the on position. Confirm that the green front panel power indicator is illuminated. There are no adjustments on the mux/demux, but there are dip switches located on the rear panel of the unit. Switches 1-4 should be disabled or in the down position for asynchronous data communication. Switch 5 is a local loopback enable switch; under normal operation it is disabled and is only activated for diagnostic purposes. Switch 6 is remote loopback diagnostics switch; under normal operation it is disabled and is only activated for diagnostic purposes. Under normal operation when data is being reliably passed through the mux, the green front panel DEMUX SYNC and REMOTE DEMUX SYNC indicators will be illuminated and the yellow LOOPBACK MODE indicator will be off. An illuminated red LOW OPTICAL POWER ALARM indicates that the received optical power is within 3dB of the low limit.

If power is normal and the dip switches are set correctly, check the following:

A. If the green DEMUX SYNC indicator(s) on one or both units is (are) not illuminated, this indicates that data is not being sent in the associated direction. This fault indication indicates that there are bad optical fibers or connections (this is the existing base fiber provided for our use to get our signal from Base Operations to Building 1194). Diagnostics can be performed on the multiplexers by looping them back on themselves (MUX OUT to DEMUX IN) using a short fiber jumper. If both sync indicators do not illuminate, the unit is defective.

B. If all green SYNC indicators are illuminated but a data channel is not working, this indicates a bad RS232 line driver or bad receiver in one of the units. Try the LOCAL LOOPBACK TEST by placing dipswitch 5 in the enabled position on the affected unit. This test can be performed with no fiber connected, which confirms the proper operation of the mux/demux circuits in the unit but not the optical channel. The green front panel DEMUX SYNC and REMOTE DEMUX SYNC indicators will be illuminated.

C. If there is no communication to any of the field sensors, the remote possibility exists that the circuit breakers feeding both power zones (at Buildings 1360 and 1361) have tripped or been turned off. Qualified personnel should be dispatched to evaluate and if needed restore power. The supply voltages and available fault current at these locations are extremely dangerous and can severely injure or kill.

2. If all of the IVS 2000s in a cabinet, for example cabinet 1 (loops 1 and 2) show failure, the most probable failure is in one of the fiber optic to 232 converters or the circuit breaker in the cabinet has tripped. First check the circuit breaker. If it is not tripped, then verify that 120 volt power (110-120 Vac) is present on the secondary side (X1-X2) of the control power transformer. Note that 480 volts enter these cabinets at the incoming terminal block and are fed to the primary of the Control Power Transformer; hence, the same warning applies as in item 1C above. No voltage here indicates a blown fuse in the cabinet. The fuse holder will illuminate if power is present on the line side of the fuse, but the fuse is blown. If the fuse is blown, investigate for the source of the overcurrent condition prior to replacing the fuse. Low voltage, less than 100 Vac, indicates a high-resistance power connection in

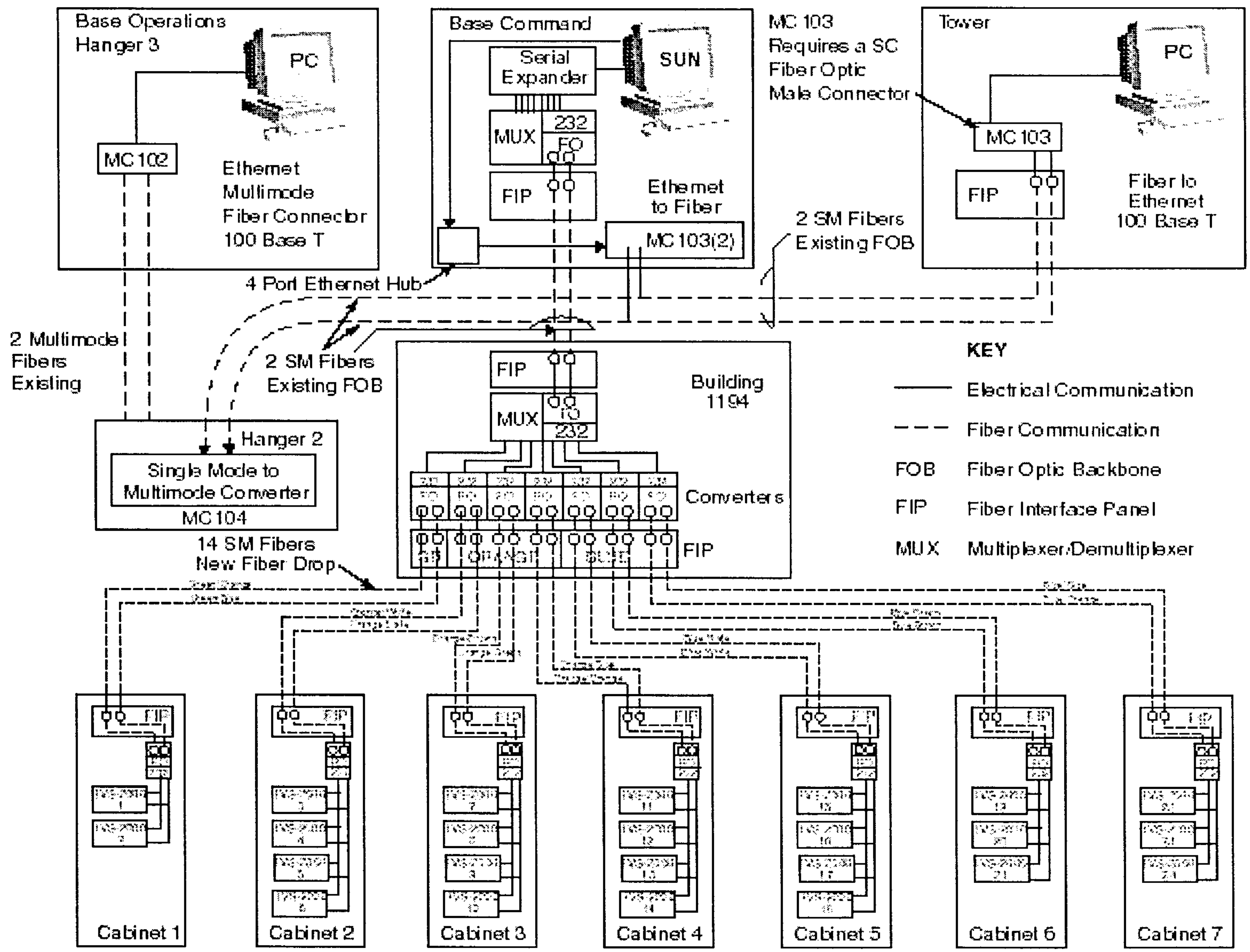

Figure 9. MacDill Hardware Block Diagram

the system; if the voltage drops below 100 Vac, the cabinet electronics will not function reliably. With power removed, inspect for loose and/or dirty connections at the cabinet terminal blocks, degrading splice connections in the power distribution cables, and loose connections at the distribution source circuit breaker (Buildings 1360 and 1361).

If power is normal but none of the loop detectors are communicating, check the following:

A. The model 4141A data modems have an internal slide switch that determines which pin of the DB25 connector is used for transmit data input (TD) and for receive data output (RD). The switch is accessed by removing the metal housing that is secured by ring nuts on the rear optical ports. The data modem must be configured as a DTE at Building 1194 and as a DCE at the field equipment cabinet.

B. If the switch is set correctly and the cables are secure, check that power is on at the unit by measuring the voltage between pin 6 and 7 of the DB25 connector on the unit. The voltage should be at least +8VDC; if not replace the power supply.

C. Verify that the RS232 signal is coming in on the correct pin: pin 2 for DCS mode, pin 3 for DTE mode. The voltage should be at least 4.5V positive in one data state and no more than 0 VDC in the other data state for proper operation. If the voltages do not meet these conditions, replace the signal source.

D. The following optical measurements require that the transmit LED be on continuously. This can be done easily by removing the modem from the serial port, applying DC power via the phone jack, and installing a jumper wire between pin 6 and pin 2 (DCE mode) or pin 3 (DTE mode). Check that the transmit LED is on when the voltage on the data input is high. Do this by connecting an optical power meter to the TX port with an optical fiber jumper. The power reading should be no less than the spec for the type of fiber used in the jumper. If the meter reading is low, replace the 4141A.

E. Reconnect the fiber optic cable to the modem and proceed to the receiver section of the modem at the far end of the fiber. Connect the optical power meter to the fiber at the RX input port of the modem. The meter should read at least –41 dBm when the transmit LED is on; if it does not, there is a problem with the fiber or fiber connections causing excessive signal loss.

F. If the received optical power is OK, check that the voltage on the RX data pin is at least +5 VDC when the optical signal is greater than or equal to –41 dBm. This can also be checked at the bench by using a short fiber jumper to loop the optical signal from the local transmitter back into the receiver. If the RX data voltage does not go high when the voltage on and the TX data pin is high, replace the modem.

G. At this point, the fiber optic link has been checked. The only remaining component is the RS232 connections between the host equipment and the modem. Check continuity with a voltmeter to ensure that the right signals are going to the right pins of the DB25 connector. If the problem is not found, replace the converter unit in cabinet 1. If this doesn't fix the problem, replace the 232 to fiber optic converter in Building 1194 that connects to cabinet 1. If all of the IVS-2000s in any of the other cabinets show failure, Loops 3–6 (cabinet 2), Loops 7–10 (cabinet 3), Loops 11–14 (cabinet 4), Loops 15–18 (cabinet 5), Loops 19 –21 (cabinet 6), or (Loops 22 –24 Cabinet 7), repeat the troubleshooting procedure listed above for cabinet 1 for the failed cabinet.

1. If only a single IVS 2000 in a cabinet is shown not working, that unit should be replaced with a spare unit.
2. If there is a problem with both remote displays not receiving track updates, the four- port hub should be checked to make sure that the power-on lamp is on. If not, try to turn on power to the unit. If power will not come on, the unit needs to be replaced. Check to make sure that the Normal/Uplink push button is in the normal position.
3. If only one of the two remote displays is not receiving track updates, then if the Tower display is not receiving updates, check that the power-on lamp on the MC 103 –10 in Base Command is on and that the fuses are OK. If this unit is working, check that the power-on lamp on the MC103 –10 in the Tower is on and that the fuses are OK. If power is on and the fuses are OK on both the MC103 –10 units, first switch the wire from the working channel on the four-port hub to make sure that the problem is not in the hub. If the display is not working properly, the Internet card in the remote display needs to be replaced.
4. If the problem is that the remote display in Base Operations is not being updated with track information, first switch the wire from the working channel on the four- port hub to make sure that the problem is not in the hub. If the display is still not receiving track updates, then the Internet card in the remote display needs to be replaced.
5. If the system indicates that all the loops from cabinets 1, 2, 3, and 4 are not responding, then check the 480 Vac power Building 1360. If loops from cabinets 5, 6, and 7 are not responding then check the 480 Vac power from Building 1361.

Figure 9 is a diagram of the hardware.

6.0 SUMMARY

This software user's manual is the result of the first phase of the effort to detect, classify, and track aircraft at MacDill Air Force Base. It is ORINCON's first attempt to determine whether inductive loops can be used to identify runway incursion situations.

The software developed is the preliminary result of this first phase. Enhancements and additional features are being planned for the next phase.

☆U.S. GOVERNMENT PRINTING OFFICE: 2000-510-079-81248

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